OMP-18 development: simple sardine Harvest Control Rules

C.L. de Moor*

Correspondance email: *carryn.demoor@uct.ac.za*

Introduction

The sardine Harvest Control Rules (HCR) of the Candidate Management Procedures (de Moor 2018a,b) for the joint South African sardine and anchovy Operational Management Procedure (OMP) OMP-18 contain a number of constraints. While some of these constraints have been recently included, others have been included in former OMPs. The constraints have generally been introduced to either aid industry stability, or to more realistically model perceived future DAFF management responses. This document considers some simple sardine Harvest Control Rules, designed in part to aid the understanding of the impact of some of these constraints.

Method

The following alternative sardine HCRs are tested (Appendix 1):

i) Constant proportion of survey estimated biomass, with an absolute minimum TAC of 10 000t.

ii) Constant proportion of survey estimated biomass above 350 000t; quadratically decreasing metarule below a survey estimated biomass of 350 000t, with an absolute minimum TAC of 10 000t.

iii) As per (i), subject to a maximum inter-annual decrease of 50%, with an absolute minimum TAC of 10 000t.

iv) Constant proportion of survey estimated biomass above 350 000t, subject to a maximum inter-annual decrease of 50%; quadratically decreasing metarule below a survey estimated biomass of 350 000t, subject to a maximum inter-annual increase[1] or decrease of 50%, with an absolute minimum TAC of 10 000t. Linear smoothing is applied between 300 000t and 350 000t to ensure no discontinuity arises due to different constraints on increases in the TAC above and below 350 000t.

v) As per (iv), with a stable TAC of 65 000t.

vi) As per (v), with a maximum TAC of 200 000t.

The inter-annual variability under the meta-rule was selected to match that defined as "Option (i)" by de Moor (2018b) so that linear smoothing is not required above 350 000t for the above cases. This is because the constraints on inter-annual decreases are the same above and below the Critical Biomass threshold of 350 000t. These cases are compared with the "Option i)" scenario with $c^S_{stbl} = 65$ and $p^S_{crit} = 0.5$ from de Moor (2018b), with the new addition of linear smoothing between 300 and 350 000t as per cases (iv) to (vi) above. This is called case (vii) in this document.

The sardine and anchovy Operating Models (OM) used to simulation test these alternative rules are the same as those used by de Moor (2018b). All projections are undertaken assuming the interim OMP-18 anchovy HCR (de Moor 2018b).

* MARAM (Marine Resource Assessment and Management Group), Department of Mathematics and Applied Mathematics, University of Cape Town, Rondebosch, 7701, South Africa.

[1]The maximum of 10 000t or $0.5 \times TAC^S_{y-1}$ is used as the constraint.

Results and discussion

The alternative HCRs were all tuned to a sardine risk < 0.15. The corresponding β control parameters are given in Table 1, generally showing a decrease in β under the inclusion of constraints on inter-annual decreases and that of a stable TAC. The changes in β can be seen in the different slopes of the HCR above 350 000t plotted in Figure 1. In order to show the impact of the constraint on inter-annual changes in the TACs, cases (iii) to (vi) are plotted assuming four different values for the TAC in the previous year. The flattening of the HCR for cases (iv)-(vi) at 30 000t given $TAC_{y-1}^{S} = 20$ is due to the constraint on increasing the TAC by at most the maximum of 50% of $TAC_{y-1}^{S} = 20$ or 10 000t. Linear smoothing between this constraint and the stable TAC of 65 000t can also be seen for cases (iv)-(vi) when $TAC_{y-1}^{S} = 20$.

The introduction of the stable TAC is clearly evident in Figure 1 for cases (v) and (vi), and this stable TAC reduces the average predicted total catch, while increasing the median predicted total catch (Figure 2). The introduction of constraints in the HCRs, thereby reducing inter-annual variability in the TACs in years for which the survey estimate of biomass is simulated to change substantially from that of the former year (cases (iii) to (vii) compared to (i) and (ii)), substantially reduces the 95%ile of the predicted MAV (Figures 2 and 3).

The 200 000t maximum directed sardine TAC constraint, used in cases (v) to (vi) results in a higher β control parameter (Table 1), but little difference in the performance statistics from this OM that does not account for the possibility of a pulse in sardine during the projection period (Table 2, Figure 2).

A tighter constraint on the inter-annual decrease in TACs for survey estimates of biomass above 350 000t, results in a lower β control parameter (Table 1), and (by design) less inter-annual variability in catches in median terms (Table 2, Figure 2 and 3).

References

de Moor CL. 2018a. OMP-18 development: alternative constraints on the sardine Harvest Control Rule. DAFF: Branch Fisheries Document FISHERIES/2018/MAY/SWG-PEL/07rev.

de Moor CL. 2018b. OMP-18 development: alternative constraints relating to the sardine Critical Biomass metarule. DAFF: Branch Fisheries Document FISHERIES/2018/MAY/SWG-PEL/12.

Table 1. The sardine control parameter β that results from tuning the HCR alternative cases to a risk<0.15. All HCRs are subject to an absolute minimum TAC of 10 000t.

	β	Metarule < 350 000t?	Metarule constraints?	Constraints above 350 000t?	Stable TAC	Maximum TAC
(i)	0.128	No	-	No	None	None
(ii)	0.159	Yes	No	No	None	None
(iii)	0.108	No	-	50%↓	None	None
(iv)	0.114	Yes	50%↑↓ with linear smoothing	50%↓	None	None
(v)	0.085	Yes	50%↑↓ with linear smoothing	50%↓	65 000t	None
(vi)	0.088	Yes	50%↑↓ with linear smoothing	50%↓	65 000t	200 000t
(vii)	0.081	Yes	50%↑↓ with linear smoothing	20%↓ with linear smoothing	65 000t	200 000t

Table 2. Sardine performance statistics for some of the alternative sardine Harvest Control Rules. All HCRs are tuned to a risk of <0.15. Where appropriate, medians [90% probability intervals] are provided, and in some cases **means** are provided in **bold**. All biomasses are given in thousands of tons.

Performance Statistic	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
β	0.128	0.159	0.108	0.114	0.085	0.088	0.081
$Risk^S$	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
p(TAC^S<20)	0.07	0.19	0.07	0.10	0.07	0.07	0.07
$\boldsymbol{\bar{B}^S_{tot,2036}}$	**263**	**252**	**268**	**265**	**273**	**274**	**274**
$B^S_{tot,2036}$	218 [73,605]	211 [73,578]	223 [71,616]	220 [71,608]	225 [72,621]	227 [72,628]	226 [71,632]
$\boldsymbol{\bar{B}^S_{west,2036}}$	**130**	**127**	**131**	**131**	**133**	**133**	**133**
$B^S_{west,2036}$	92 [15,373]	89 [15,355]	93 [14,383]	92 [15,381]	92 [14,393]	92 [14,392]	92 [15,393]
$\boldsymbol{\bar{B}^S_{south,2036}}$	**133**	**125**	**136**	**135**	**140**	**141**	**140**
$B^S_{south,2036}$	110 [36,312]	103 [33,292]	114 [35,323]	112 [35,320]	116 [36,336]	116 [36,338]	117 [36,338]
$\frac{B^S_{tot,2036}}{B^S_{tot,2015}}$	2.8 [0.7,15.6]	2.7 [0.7,15.2]	2.8 [0.7,15.9]	2.8 [0.7,15.9]	2.8 [0.7,16.3]	2.8 [0.7,16.2]	2.8 [0.7,16.4]
$\frac{B^S_{west,2036}}{B^S_{west,2015}}$	2.0 [0.3,14.7]	2.0 [0.3,13.9]	2.0 [0.3,15.1]	2.0 [0.3,14.9]	2.1 [0.3,15.2]	2.1 [0.3,15.2]	2.1 [0.3,15.2]
$\frac{B^S_{south,2036}}{B^S_{south,2015}}$	0.6 [0.2,1.7]	0.6 [0.2,1.6]	0.6 [0.2,1.7]	0.6 [0.2,1.7]	0.6 [0.2,1.8]	0.6 [0.2,1.8]	0.6 [0.2,1.8]
$B^S_{tot,min}$	100 [42,176]	96 [40,168]	102 [40,180]	101 [41,178]	103 [42,182]	103 [41,181]	103 [42,182]
$B^S_{west,min}$	20 [3,55]	20 [3,54]	20 [3,54]	20 [3,54]	20 [3,54]	20 [3,55]	20 [3,53]
$B^S_{south,min}$	45 [14,95]	41 [9,88]	47 [14,98]	46 [14,96]	49 [16,98]	49 [16,99]	49 [16,98]
$\boldsymbol{\bar{C}^S_{tot}}$	**81**	**93**	**74**	**77**	**69**	**67**	**68**
C^S_{tot}	60 [17,214]	73 [10,257]	59 [20,189]	59 [14,199]	65 [16,151]	65 [16,151]	65 [16,151]
Med C^S_{tot}[2]	61 [36,99]	74 [32,118]	59 [34,94]	61 [33,99]	65 [42,75]	65 [42,76]	65 [40,83]
$\boldsymbol{\bar{C}^S_{west}}$	**58**	**62**	**55**	**56**	**52**	**52**	**52**
C^S_{west}	45 [14,145]	51 [9,164]	44 [15,132]	45 [11,137]	49 [13,112]	50 [13,112]	50 [13,113]
$\boldsymbol{\bar{C}^S_{south}}$	**23**	**30**	**19**	**21**	**16**	**15**	**16**
C^S_{south}	10 [0,84]	14 [0,115]	10 [0,69]	10 [0,75]	10 [0,48]	10 [0,47]	11 [0,48]
$\frac{C^S_{west}}{C^S_{tot}}$	0.81 [0.40,1.0]	0.80 [0.35,1.0]	0.82 [0.42,1.0]	0.82 [0.41,1.0]	0.82 [0.44,1.0]	0.82 [0.44,1.0]	0.82 [0.44,1.0]
$\boldsymbol{\overline{ByC}^S_{tot}}$	**17.8**	**17.9**	**17.7**	**17.8**	**17.7**	**17.7**	**17.7**
ByC^S_{tot}	10.5 [1.4,58.1]	10.6 [1.4,58.2]	10.5 [1.4,58.0]	10.5 [1.4,58.1]	10.4 [1.4,57.9]	10.4 [1.4,57.9]	10.4 [1.4,57.9]
$\boldsymbol{\overline{ByC}^S_{west}}$	**17.8**	**17.9**	**17.7**	**17.8**	**17.7**	**17.7**	**17.7**
ByC^S_{west}	10.5 [1.4,58.1]	10.6 [1.4,58.2]	10.4 [1.4,58.0]	10.5 [1.4,58.0]	10.4 [1.4,57.9]	10.4 [1.4,57.9]	10.4 [1.4,57.9]
$\boldsymbol{\overline{ByC}^S_{south}}$	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
ByC^S_{south}	0 [0.0,0.0]	0 [0.0,0.1]	0 [0.0,0.0]	0 [0.0,0.0]	0 [0.0,0.0]	0 [0.0,0.0]	0 [0.0,0.0]
MAV^S_{tot}[3]	0.57 [0.35,0.77]	0.69 [0.39,0.90]	0.50 [0.33,0.50]	0.50 [0.36,0.50]	0.46 [0.14,0.50]	0.45 [0.15,0.50]	0.36 [0.13,0.50]
MAV^S_{west}	0.48 [0.30,0.67]	0.59 [0.34,0.81]	0.41 [0.27,0.54]	0.43 [0.29,0.54]	0.37 [0.21,0.50]	0.37 [0.21,0.50]	0.34 [0.19,0.50]
MAV^S_{south}	0.92 [0.67,1.0]	0.97 [0.76,1.1]	0.82 [0.56,1.0]	0.82 [0.58,1.0]	0.80 [0.54,1.0]	0.81 [0.53,1.0]	0.79 [0.50,1.0]

[2] This gives the median and 90%ile of the 1000 median catches.

[3] $MAV^{S,b} = median\{(C^{S,b}_{tot,y} - C^{S,b}_{tot,y-1})/C^{S,b}_{tot,y-1}\}$

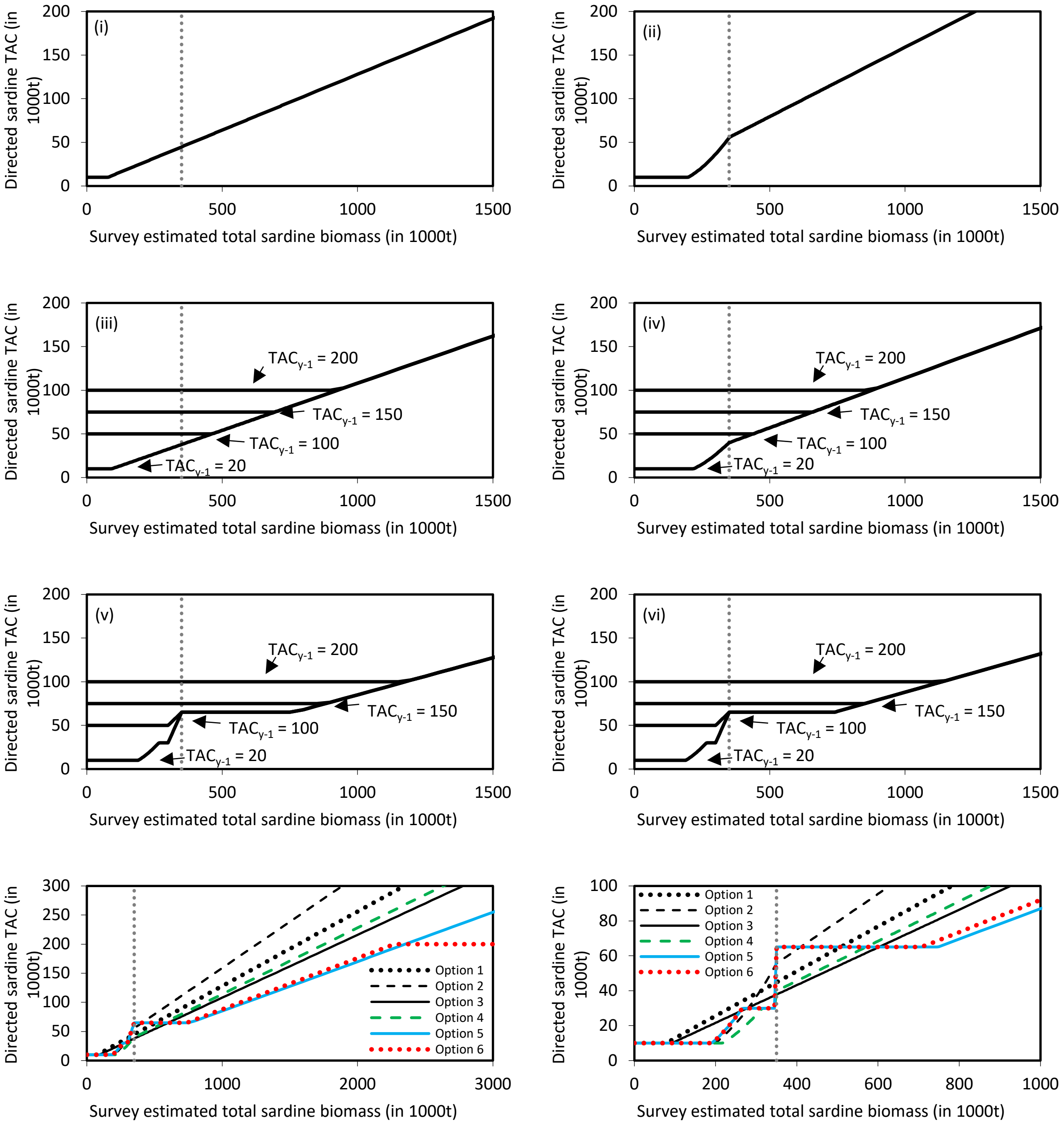

Figure 1. The Harvest Control Rules for cases (i) to (vi). The cases with constraints on inter-annual changes in the TAC are shown for four alternative possible values for the previous year's TAC. The lower two plots compare the cases against one another, on different scales, assuming $TAC_{y-1}^{S} = 20$.

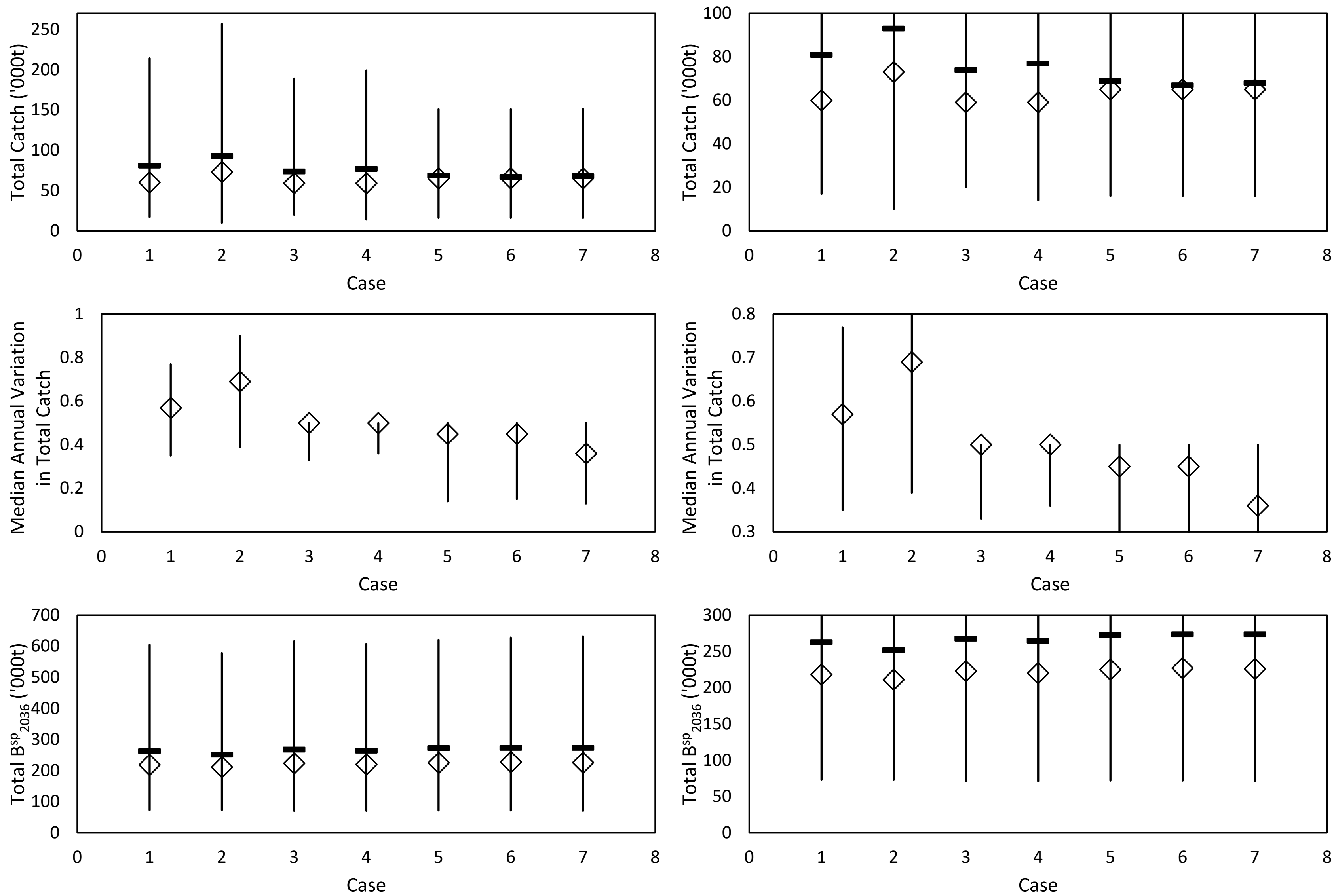

Figure 2. The median (diamond), mean (bar) and 90% probability intervals for total directed sardine catch (upper panels) and median annual variation in catch (middle panels), and total spawner biomass after 20 year projection (lower panels) tuned to risk of <0.15 for all HCRs tested in this document. The right hand panels show the results over a smaller range.

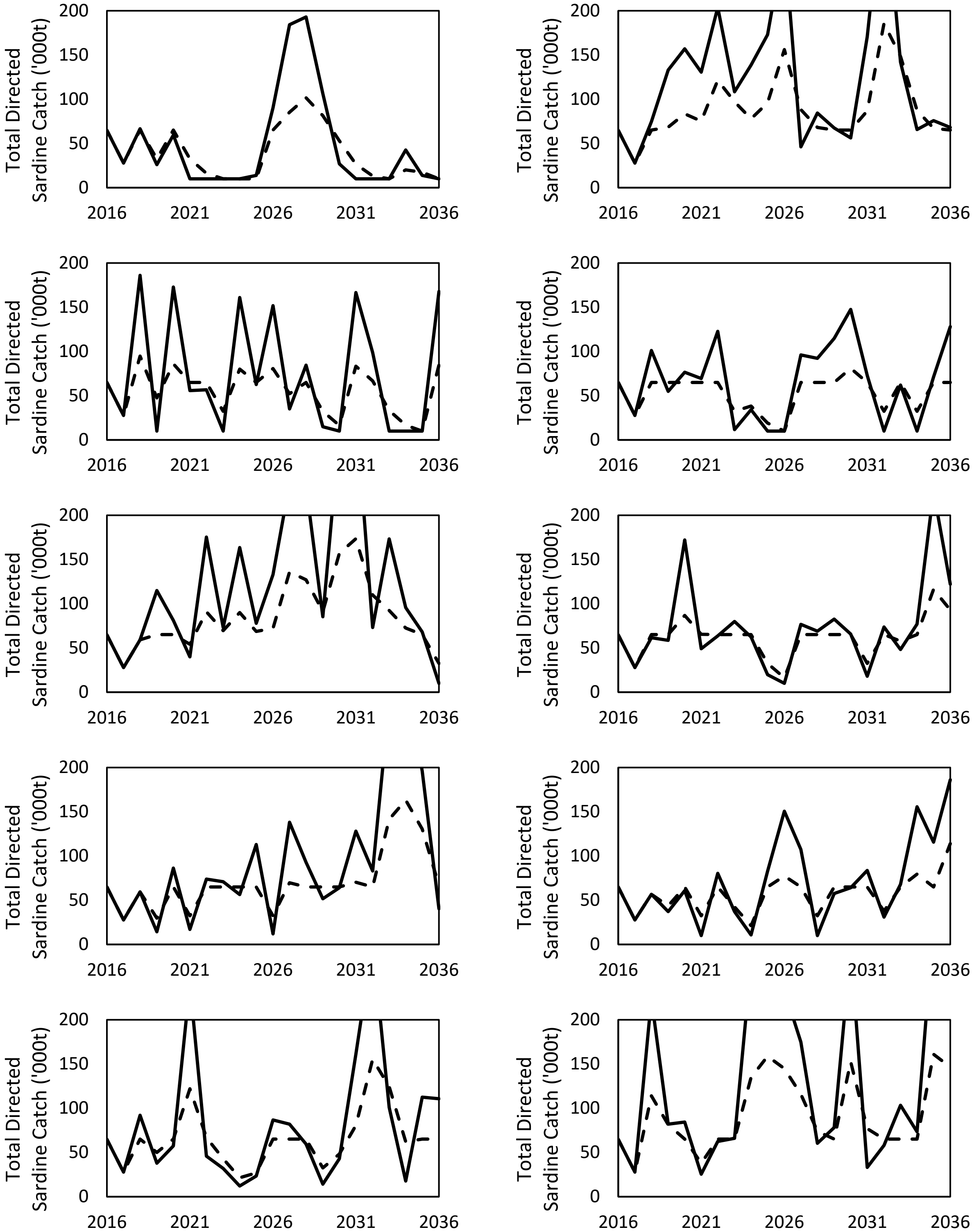

Figure 3. Trajectories of total directed sardine catch from 10 simulations. Trajectories are shown for cases (ii) and (vii) which had the highest and lowest median MAV (Figure 2).

Appendix A: Sardine Harvest Control Rules

Defining $B_{y-1}^{obs,S}$ as the November survey estimate of sardine total biomass in year $y-1$ (in thousands of tons), the directed >14cm sardine TAC (TAC_y^S in thousands of tons) is calculated using the following alternative HCRs:

i) $TAC_y^S = \beta B_{y-1}^{obs,S}$ subject to: $TAC_y^S \geq 10$

ii) If $B_{y-1}^{obs,S} \geq 350$: $TAC_y^S = \beta B_{y-1}^{obs,S}$

$$\text{If } B_{y-1}^{obs,S} \leq 350\text{: } TAC_y^S = \begin{cases} 0 & if\ \frac{B_{y-1}^{obs,S}}{350} < 0.25 \\ \beta \times 350\left(\frac{\frac{B_{y-1}^{obs,S}}{350}-0.25}{1-0.25}\right)^2 & if\ 0.25 < \frac{B_{y-1}^{obs,S}}{350} < 1 \end{cases}$$

subject to: $TAC_y^S \geq 10$

iii) $TAC_y^S = \beta B_{y-1}^{obs,S}$ subject to: $TAC_y^S \geq max\{(1-0.5)TAC_{y-1}^S; 10\}$

iv) If $B_{y-1}^{obs,S} \geq 350$: $TAC_y^S = \beta B_{y-1}^{obs,S}$ subject to: $TAC_y^S \geq max\{(1-0.5)TAC_{y-1}^S; 10\}$[4]

$$\text{If } B_{y-1}^{obs,S} \leq 350\text{: } TAC_y^S = \begin{cases} 0 & if\ \frac{B_{y-1}^{obs,S}}{350} < 0.25 \\ \beta \times 350\left(\frac{\frac{B_{y-1}^{obs,S}}{350}-0.25}{1-0.25}\right)^2 & if\ 0.25 < \frac{B_{y-1}^{obs,S}}{350} < 1 \end{cases}$$

subject to $max\{(1-0.5)TAC_{y-1}^S; 10\} \leq TAC_y^S \leq (1+0.5)TAC_{y-1}^S$

To maintain continuity in the TAC as the Critical Biomass threshold of 350 000t is approached from above and below, and defining TAC_y^{S300} and TAC_y^{S350} as the TAC output from the above equations when $B_{y-1}^{obs,S} = 300$ and $B_{y-1}^{obs,S} = 350$, respectively, the following linear smoothing is applied if $300 \leq B_{y-1}^{obs,S} \leq 350$ and the constraint on increasing/decreasing the TAC would have normally be applied at $B_{y-1}^{obs,S}$:

$$TAC_y^S = \left(1 - \frac{350-B_{y-1}^{obs,S}}{50}\right)TAC_y^{S350} + \left(\frac{350-B_{y-1}^{obs,S}}{50}\right)TAC_y^{S300}$$

v) If $B_{y-1}^{obs,S} \geq 350$: $TAC_y^S = \beta B_{y-1}^{obs,S}$ subject to: $TAC_y^S \geq max\{(1-0.5)TAC_{y-1}^S; 65\}$[2]

$$\text{If } B_{y-1}^{obs,S} \leq 350\text{: } TAC_y^S = \begin{cases} 0 & if\ \frac{B_{y-1}^{obs,S}}{350} < 0.25 \\ 65\left(\frac{\frac{B_{y-1}^{obs,S}}{350}-0.25}{1-0.25}\right)^2 & if\ 0.25 < \frac{B_{y-1}^{obs,S}}{350} < 1 \end{cases}$$

subject to $max\{(1-0.5)TAC_{y-1}^S; 10\} \leq TAC_y^S \leq (1+0.5)TAC_{y-1}^S$

To maintain continuity in the TAC as the Critical Biomass threshold of 350 000t is approached from above and below, and defining TAC_y^{S300} and TAC_y^{S350} as the TAC output from the above equations when $B_{y-1}^{obs,S} = 300$ and

[4] Note, no linear smoothing is required in this case as the constraint on inter-annual decrease is consistent above and below the Critical Biomass threshold of 350 000t.

$B_{y-1}^{obs,S} = 350$, respectively, the following linear smoothing is applied if $300 \leq B_{y-1}^{obs,S} \leq 350$ and the constraint on increasing/decreasing the TAC would have normally be applied at $B_{y-1}^{obs,S}$:

$$TAC_y^S = \left(1 - \frac{350 - B_{y-1}^{obs,S}}{50}\right) TAC_y^{S350} + \left(\frac{350 - B_{y-1}^{obs,S}}{50}\right) TAC_y^{S300}$$

vi) If $B_{y-1}^{obs,S} \geq 350$: $TAC_y^S = \beta B_{y-1}^{obs,S}$ subject to: $max\{(1-0.5)TAC_{y-1}^S; 65\} \leq TAC_y^S \leq 200$[2]

If $B_{y-1}^{obs,S} \leq 350$: $TAC_y^S = \begin{cases} 0 & if\ \frac{B_{y-1}^{obs,S}}{350} < 0.25 \\ 65\left(\frac{\frac{B_{y-1}^{obs,S}}{350} - 0.25}{1-0.25}\right)^2 & if\ 0.25 < \frac{B_{y-1}^{obs,S}}{350} < 1 \end{cases}$

subject to $max\{(1-0.5)TAC_{y-1}^S; 10\} \leq TAC_y^S \leq (1+0.5)TAC_{y-1}^S$

To maintain continuity in the TAC as the Critical Biomass threshold of 350 000t is approached from above and below, and defining TAC_y^{S300} and TAC_y^{S350} as the TAC output from the above equations when $B_{y-1}^{obs,S} = 300$ and $B_{y-1}^{obs,S} = 350$, respectively, the following linear smoothing is applied if $300 \leq B_{y-1}^{obs,S} \leq 350$ and the constraint on increasing/decreasing the TAC would have normally be applied at $B_{y-1}^{obs,S}$:

$$TAC_y^S = \left(1 - \frac{350 - B_{y-1}^{obs,S}}{50}\right) TAC_y^{S350} + \left(\frac{350 - B_{y-1}^{obs,S}}{50}\right) TAC_y^{S300}$$